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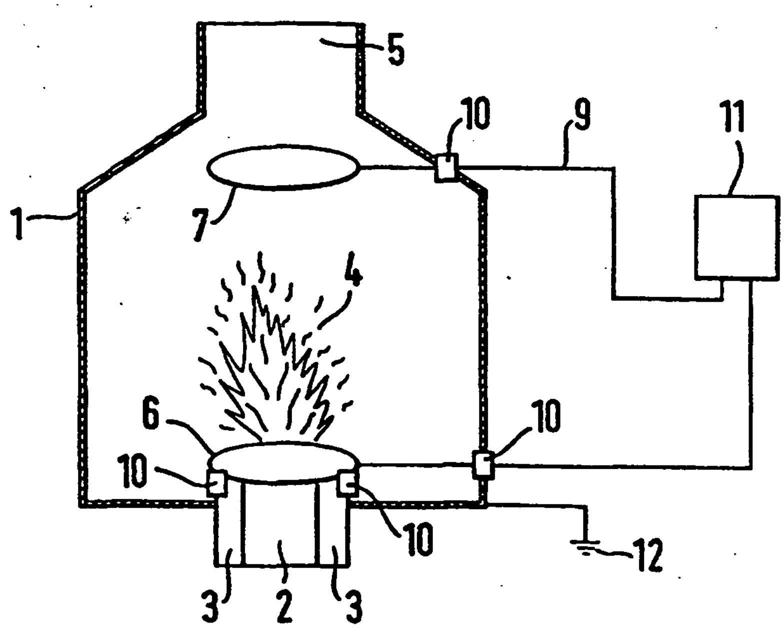
(57) Abstract

An electrode device has been developed for use in combustion chambers, such as all types and sizes of stoves and fireplaces. One or more electrodes are located in such a manner that the flame zone is located between two of the electrodes. An electrode system is also located in the inlet opening for combustion air in order to inonize/excite the air which is used in the combustion process. The combustion chamber can also be employed as an electrode or be connected to one of the electrodes. The electrodes and possibly also the combustion chamber are connected to electrical voltage, thus forming poles in an electrical system. The voltage and polarity are selected in order that the combustion is affected in the flame zone, thus reducing the content of smoke particles, hydrocarbons, carbon monoxide and nitrous components in the exhaust gas.



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AN ELECTRODE ARRANGEMENT FOR USE IN A COMBUSTION CHAMBER

The present invention concerns an electrode device for use in combustion chambers. The combustion chamber can be any type and size of stove and fireplace, designed as a container with an inlet for the supply of fuel and an oxidation means in the form of air and with an outlet for exhaust gas.

In the context of the constant increase in requirements for improving the control of combustion processes and emissions from combustion processes, there is a need to produce new technical solutions in the form of devices whose utilization will enable combustion processes to be controlled. by achieving control of combustion rate. combustion energy and the emission of harmful components from the combustion process.

The invention is especially concerned with electrodes and discharge factors which when tested have been shown to be capable of acting efficiently as control systems for combustion processes. the electrical system affecting the entire combustion process including air. fuel, smouldering, flame. exhaust gas, particles and chamber surfaces such as walls, top and bottom.

In connection with the combustion of combustible materials in all types of combustion chamber. for example large and small stoves, fireplaces. enclosed fireplaces. smelting furnaces. boilers. etc., the need has arisen in recent times for a reduction in the emission of harmful substances into the environment. Restrictions have been established by law in the form of international agreements in which emission norms are stipulated. It is assumed that more stringent requirements will be specified in the future. thus requiring the constant development of methods and devices which will be capable of fulfilling the future national and international conditions. The requirements are particularly concerned with the emission of substances such as hydrocarbons. carbon monoxide, nitrous gases and particulate material. This application concerns devices which when tested have proved to be capable of efficiently controlling the combustion process and/or emissions. the combustion phase or gas phase being affected by the devices as described in the claims.

If combustible materials are burned in traditional combustion chambers. the quality of combustion is to a great extent left to chance. It has been shown

that the often random access of the combustion mass and the exhaust gas to oxygen does not permit a maximum degree of combustion of the fuel and the exhaust gases. This applies particularly during the period before the actual main combustion occurs, i.e. during the first combustion phase and during the period when there is characteristic smouldering in the combustion chamber. Measurements have established that the emission of uncombusted organic material in the form of hydrocarbons and the poisonous gas carbon monoxide increases when the flame intensity and the rate of combustion decrease. Point measurement of the oxygen content in and around the combustion shows that the flame receives most oxygen in the part which is closest to the opening for air input and least at the back of the flame. An analysis of the proportion of the mixture of air/combustible gas in the zone above the flame shows that the proportions of the mixture are uneven when efficient afterburning of the gases is not achieved. The upper combustion zone lacks oxygen and has too low a temperature.

Traditional combustion chambers are normally equipped with inlets for combustion air, combustion mass and outlets for flue gas. In most cases the degree of combustion is regulated by altering the proportions of the mixture of combustible material and air. As a rule the optimum conditions in the actual combustion centre cannot be altered in order to obtain a combustion pattern which is environmentally and economically attractive. In most cases one factor increases if the other is reduced. An example of this is the relationship between a low degree of combustion and the emission of harmful components from the combustion process. If the combustion temperature is reduced, the flue gas temperature drops and the proportion of uncombusted volatile harmful substances in the exhaust gas is increased with the consequence that substances are passed into the natural environment which are invidious and difficult to break down.

The object of the present invention is to obtain devices which provide efficient combustion in a combustion chamber with open flame combustion. A further object is to reduce harmful substances in the exhaust gas.

The invention concerns an electrode and discharge system, the effect of which, when used in or in connection with combustion chambers, is that the normally fixed combustion conditions do not follow traditional physical and chemical patterns, but deviate in such a manner that it becomes possible to

perform combustion, for example, at a low temperature while still keeping the emissions of harmful substances to a minimum or completely eliminating them. The invention is described in the patent claims and in the figures.

The object of the electrode system which forms part of the invention is to form electrical and electromagnetic fields, discharges and conditions which influence combustion reactions to proceed in an optimum manner with reduced emissions of undesirable products such as, for example, particulate material (PM), carbon monoxide gas (CO), environmentally harmful, uncombusted organic material (HC) and nitrous compounds. In this context the term "discharges" does not principally refer to processes such as jump sparks, but, for example, discharges such as corona discharge or electrode discharges without a spark ("silent discharge"). The type of discharge with be determined by the form of electrode, where pointed or thin electrodes will substantially give corona discharges, while flat electrodes will give spark-free discharges characterized as "silent discharge".

By employing pulsed direct current, it is possible to impress a higher voltage and thereby a stronger electrical field without the formation of jump sparks between the electrodes. Thus the frequency of the current is important for controlling the discharge process. The frequency also gives rise to electromagnetic conditions which can influence the combustion in a positive direction.

It is assumed that the discharges and the electrical field affect the reactants in the combustion process by excitation, dissociation, ionizing, dissociative ionization, or by the formation of free radicals. Each of these processes separately can contributes to increasing the efficiency of the combustion reaction.

The effect of the reaction pattern on the combustion process is determined by voltage, frequency and type of discharge. It has also been observed that the exhaust gas can be affected and controlled by the influence of electricity, since the exhaust gas can be conveyed back to the combustion zone and participate in a more complete combustion reaction.

Tests show that emissions of uncombusted hydrocarbons, carbon monoxide and particulate material are reduced by means of the invention and that

nitrous compounds become less unstable with less of the natural nitrogen component in the combustion air being converted to NOx. The total electrical influence leads to conditions which increase the potential for influencing the combustion pattern in a positive direction. since the incandescence. the flame intensity and the flame pattern. together with the exhaust gas can be controlled to a very great extent by means of the described influences.

The invention will now be explained in more detail by means of embodiments which are disclosed in the attached drawings, which illustrate in purely schematic form the principle of a design of the invention. Other embodiments may also be used.

Figure 1 is a section of a combustion chamber preferably intended for liquid and gaseous fuels.

Figure 2 is a section of a combustion chamber preferably intended for solid fuels.

Figure 3 is a section of a combustion chamber with an outlet for exhaust gas in one of the sides.

Figure 4 illustrates various forms of electrodes.

Figure 1 illustrates a combustion chamber 1 with an inlet 2 for fuel in the lower part of the combustion chamber. The fuel can be gaseous or liquid. but all types of fuel can be employed. Around the fuel inlet 2 there is coaxially located an inlet 3 for an oxidation means such as air. The air inlet 3 may also be located beside the fuel inlet 2. The reference numeral 4 indicates the flame zone. In the upper part of the combustion chamber is an outlet 5 for exhaust gas. At the fuel inlet 2 and the air inlet 3 or at the start of the flame zone 4 there are located one or more electrodes 6. The electrode 6 is electrically insulated from the combustion chamber by means of insulation material which can be in the form of a ring 10. In the upper part of the combustion chamber 1 over or around the flame zone there are located one or more electrodes 7 which are electrically insulated from the combustion chamber by means of electrical insulation material 10. The electrodes 6 and 7 are connected to a voltage generator 11 which supplies voltage to the electrodes. either direct voltage, pulsating direct voltage or alternating voltage. In the

figure electrodes 6 and 7 are coupled to a voltage generator 11 via temperature-resistant cables 9 which are inserted into the combustion chamber 1 through an insulator 10. The electrodes 6 and 7 are coupled to voltage with opposite polarity, thus forming an electrical field between the electrodes 6 and 7. There is a choice of either connecting one of the electrodes 6, 7 to the combustion chamber 1 or using the combustion chamber 1 as an electrode.

Figure 2 illustrates a combustion chamber 1 preferably for solid fuels. A fuel inlet 2 and an air inlet 3 are located in the side wall of the combustion chamber 1. An electrically conducting grate 13 forms the base for the fuel 16. The grate 13 is insulated from the combustion chamber 1 by means of heat-resistant insulators 15 which can be constructed in one piece as a ring. Ceramics can be used as insulation material. The grate 13 permits the through-flow of air and ash to fall through. For practical reasons the entire cross section of the combustion chamber 1 can be in the form of a grate. The grate 13 can also be made of an electrically neutral material. When such an embodiment is utilized, an electrode 6 is located under the grate. The reference numeral 4 indicates the flame zone. In the upper part of the combustion chamber 1 is an outlet 5 for exhaust gas. At the outlet area for exhaust gas in the upper part of the combustion chamber 1 there are located one or more electrodes 7 at or above the flame zone 4. The electrode 7 is electrically insulated from the combustion chamber 1 by means of electrical insulation material 10. The electrodes 7, 14, the grate 13 and possibly the electrode 6 are coupled to the voltage generator 11 by means of temperature-resistant cables 9 which are inserted into the combustion chamber 1 through insulators 10. The electrodes 7 and 6 are connected to voltage with opposite polarity, thus forming a field between the electrodes. The electrode 6 can have an electrical earth connection. An electrode 14 can be located in or immediately in front of the air inlet 3 for ionization of the inlet air and the combustion atmosphere. In patent application xxx from the same applicant reference is made to the use of a mixing chamber in the outlet area 5. When a mixing chamber is employed it can be used as an electrode 7, or be equipped with electrodes 7 which are insulated from the mixing chamber.
One or more electrodes 8 and 8b are located in the lower part of the combustion chamber 1 at the same height as the fuel 16 or immediately above it. The electrodes 8 and 8b are preferably located at the same level at an equal distance from each other around the fuel 16. Such electrodes can also be located in the combustion chamber 1 where liquid and gaseous fuel are

employed. The effect on the incandescence or combustion will be strongest where the field is strongest and most concentrated. In some cases. such as. for example, during heating. a slow combustion is desirable and two horizontal electrodes 8 and 8b have therefore been inserted with the object of increasing the intensity of incandescence in the combustion as required. This electrode arrangement is a kind of replacement for the effect of a traditional bellows. The obvious effect of using an electrode system of this kind is the creation of a wind-like atmosphere which blows life into the incandescence. The phenomenon can be characterized as an electron wind where the air masses are not moved in a traditional manner. but the practical effect of an electron wind is obtained between the electrodes. The object of the horizontal electrodes is to shorten the heating phase. thus reducing the period between ignition and steady combustion. As previously mentioned. it is the heating period which is the most unstable and polluting. When used in practice the horizontal electrodes should be capable of acting independently of the other electrodes. since they are activated or switched off as required. In practice it can be said that the electrodes above and below the flame zone force the exhaust gas and the particles down into the combustion and the horizontal electrodes intensify the actual incandescence. This is highly effective in those cases where a rapid burning up of the combustion material is desired. for example in the case of refuse incineration.

Figure 3 illustrates a combustion chamber 1 with a flue outlet 5 in one of the sides. In the figure the flue outlet is located at the back edge 17 of the combustion chamber 1. In the example the pair of electrodes 6 and 7 are located on each side. one on each of the chamber walls 19 and 20. The actual incandescent combustion 23 takes place in the bottom 21 of the chamber and the flame combustion 4 in the central zone of the chamber. Upper flames 22 pass between the electrodes 6 and 7 where they are influenced by the electrical field and the discharge between them. One of the electrodes 6 and 7 may be omitted and replaced by a combustion chamber wall 20 or 19 which is then employed as an electrode. The combustion chamber 1 may be used as an electrode. One of the electrodes 6 or 7 or possibly both can be mounted at a certain angle in relation to the combustion chamber walls 19 and 20 in order to give the electrical field a favourable direction in relation to the flame zone 4. The reference numeral 12 indicates the earthing point. The electrodes 6. 7 are connected to an electrical voltage generator 11 by means of cables 9 which are inserted into the combustion chamber 1 through insulators 10.

Figure 4.1 illustrates forms of electrodes where electrodes 7 and 6 are flat and circular or oval plates which are preferably located horizontally above each other. thus forming an electrode pair. In the centre of the upper and lower electrodes 7 and 6 there is located a screw 9b. which in the upper electrode 7 is surrounded by an insulating material 10. The object of the insulator 10 is to insulate the electrode 7 from the combustion chamber 1. The screw is electrically conducting and conducts electric current up to the actual electrodes 6 and 7 from cable 9. The lower electrode 6 can be connected to electric earth 12 as an alternative to voltage 11. The object of the screw arrangement 9b is that it anchors the electrode to the combustion chamber 1 and facilitates the maintenance work since the electrode 7 can easily be unscrewed and cleaned or replaced.

Figure 4.2 illustrates the electrode 7 supplied with discharge points 7a.

Figure 4.3 illustrates electrodes 7 and 7a equipped with holes 7b for gas through-flow.

Figure 4.4. The incandescence electrodes 8 and 8b are in the form of rods where a part of the rod is surrounded by insulating material 10. The electrode is connected to an electrical conductor 9 via a screw 9b. The electrodes consist of a temperature-resistant and an electrically conducting end 8c. 8d. 8e and 8f against the high temperature side. This end has voltage impressed to such a degree that a discharge occurs in the direction towards the incandescence 23. The end can either be in the form of a point 8d. a ball 8c. a plate 8e or a brush 8f, depending on which type of discharge is required.

Figure 4.5 illustrates a plate-shaped, curved plate electrode 25 as the upper electrode in combination with a flat. circular bottom electrode 6. In addition the electrode 25 can be like electrode 7 with discharge points and perforations.

Figure 4.6 illustrates a top electrode 7 in the form of a funnel in which the outer walls 28 of the funnel are impressed with voltage from the voltage generator 11 or earthed 12. In the centre of the funnel 26 there is located a current-carrying wire electrode 27 which is impressed with high voltage. The wire 27 is electrically insulated from the funnel 28 by means of an insulator 10. The wire 27 may be replaced by a brush or cord-shaped metallic

discharger. The reference numeral 24 indicates a flame zone. The electrode 26 is located around the flame zone and the electrode 27 projects down into the flame zone 24.

Figure 4.7 consists of a funnel as described under figure 4.6, but this has a narrowing in the form of a venturi 29 in the flow passage 24. The venturi 29 can either be in electrical contact with the actual funnel 26 or insulated from the funnel 26 by means of an insulator 10.

Figure 4.8 consists of a fan electrode 30 in which the fan blades 31 are impressed with electrical voltage. The electrode 31 is impressed with electrical voltage from the voltage generator 11 with opposite polarity to the surrounding reference electrode 32, or it is connected to earth 12. The fan 30 revolves due to currents from the combustion gases or it can rotate by being connected to a shaft. The reference electrode 32 can either be an independent ring or the actual combustion chamber 1. The fan electrode 30 is employed in the upper part of the combustion.

Figure 4.9 consists of a spiral-shaped electrode 32 which permits flames to flow freely between each of the spirals 33 and 34. Each isolated spiral 33 and 34 is connected to the voltage generator 11 where one of the spiral electrodes receives the opposite electrical charge to the other. In the centre of the spirals 33 and 34 there is located an electrical insulator 10 the object of which is to insulate the electrodes from one another and to act as a suspension means for the electrode 32 in the combustion chamber 1. One of the spiral electrodes 33 and 34 can be connected to earth 12.

Figure 4.10 consists of an electrode 39 which acts as an ion trap for use in the upper part of the combustion chamber where the combustion passes from the flame to the gas phase. The electrode 39 consists of an outer ring 40 and an inner core 41 held together by insulators 10. The object of this type of electrode is to obtain a powerful discharge between the ring 40 and the core 41 where upper flames and exhaust gas have to pass. It will thereby be possible to neutralize the gas or convert it to harmless components while at the same time any particles in the exhaust gas are precipitated in the field. The reference numeral 24 indicates the flow passage for combustion elements.

The electrodes illustrated in figures 1,2 and 3 together with the combustion chamber 1 can be individually coupled to electrical voltage and negative or positive polarity. Alternating voltage may also be employed. The voltage may be connected intermittently and it can also be reversed for periods.

In figures 1 and 2 electrodes 6 and 13 are preferably located under or at the lower part of the flame zone 4, connected to positive polarity. Electrode 7 in the upper part of the combustion chamber above or at the flame zone 4 is preferably connected to negative polarity. The combustion chamber 1 is normally made of metal and can also be used as an electrode. The combustion chamber 1 may, e.g., be connected to negative polarity and is used as an electrode either alone or in addition to electrode 7. The combustion chamber 1 is preferably connected to earth 12 or to a neutral point.

Other connections are also possible. For instance, the combustion chamber 1 and the lead-in pipes 2 and 3 for fuel and air respectively are connected to earth or a neutral point and electrode 7 is connected to alternating voltage, preferably high-frequency.

In figure 2 the electrodes 8 and 8b are located horizontally on the same level as the incandescent zone, thus forming a field between them. Electrode 8b is preferably connected to negative polarity and its primary purpose is to change the flame pattern or the incandescence, thus enabling, for example, long flames with a small surface area to be altered in appearance to a plurality of small tongues of flame with a substantially greater total surface area than the long flames.

The electrode 14 which is located in connection with the combustion air in the air inlet 3 is preferably connected to negative polarity and should be of such a nature that it ionizes the air which is used in the combustion. This is achieved by an electrode point consisting of one or more points, preferably points in the form of a brush where the brush consists of several thin metallic wires.

A fuel electrode can be located in connection with liquid fuel and is employed in such a manner that the fuel has the opposite polarity to the air, the electrode being connected to the actual fuel and the fuel thereby acting as a secondary electrode since the polar electrode has no other electrically

reactive components in its vicinity than the actual fuel molecules. In zones where fuel is charged, the fuel pipe should be of an insulating nature.

The electrodes can be connected to direct voltage, preferably pulsating direct voltage, i.e. direct voltage with overlaid alternating voltage. It has been shown that the pulse frequency affects the efficiency of the system. A pulse frequency between 1 Hz and 3000 MHz has been employed and it has been shown that specific pulse frequencies give a greater reduction in harmful substances in the exhaust gas when one type of fuel is used. In table 1 below there is a list of some fuels and pulse frequencies which affect the combustion in a positive direction, thus achieving a reduction in harmful substances in the exhaust gas and better combustion in individual. special types of combustion. Results have also been obtained in the form of improved combustion of exhaust gas by means of frequencies in the gigahertz range.

In future applications. a decision will have to be taken on the choice of frequency, voltage and type of discharge dependent on the nature of the fuel and the combustion chamber. It should be possible to choose any combination of electrical parameters for specific purposes without being confined to the individual values which are expressed in table 1.

The following table illustrates an example of some electrical parameters in the form of frequencies and discharge characteristics which are employed in experimentation with the combustion materials listed when used in combustion in small combustion chambers with a chamber volume of 0.75 m3. The examples are representative of conducted experiments and should not be regarded as limiting for subsequent choice of other values, e.g. other frequencies or voltages with the said fuel types.

TABLE 1

Fuel	Electrode voltage	Frequency	Polarity	Earth conductor to
Light oil:	20 KV per electrode	8 KHz	Pos.Neg.	Combustion chamber
Gas:	5 KV per electrode	8 KHz	Pos.Neg.	Combustion chamber
Charcoal:	10 KV per electrode	13.5 KHz	Neg.	Grate
Coal:	30 KV per electrode	12.5 KHz	Neg.	Grate

The pulse amplitude can be up to 100% of the direct voltage. A pulse amplitude between 10% and 50% is preferably employed. Alternating voltage, preferably high-frequency alternating voltage, can also be employed.

The magnitude of the electrical voltage which is supplied to the electrodes is dependent on the dimensions of the combustion chamber and the distance between the electrodes. The combustion temperature and the natural ionization in the combustion are also important for the voltage supplied. The strength of the electrical field in the flame zone between the electrodes can be in the range 0.01 to 25 kV/cm, preferably in the range between 0.2 and 1 kV/cm.

The power which is supplied to the electrode system is dependent on the dimensions of the combustion chamber, the design of the electrode, the fuel, the ionization of the combustion, the combustion temperature and the number of electrodes. Tests in a combustion chamber whose physical measurements are: lateral surfaces 50 cm, height 68 cm, chamber width 60 cm, show that with dry wood as fuel a substantial reduction in PM, HC and CO is already obtained when power is supplied in the range 2 to 5 watts. This is one of the advantages of the invention. During normal operation the power supplied was in the range 10 watts with a field strength between the electrodes of 0.25 kV/cm. The voltage was pulsating direct voltage with a pulse frequency in the range 12 kHz and the pulse amplitude was in the range 10% of the direct voltage. In a practical application of the invention, frequencies above the audible range will have to be used in, for example, fireplaces with or without doors. In an industrial context the audibility of the discharge is of less importance.

A flame contains countless ions. These serve as electrical charge carriers. In a flame chargeable flue gas particles are also ionized. Oxygen, carbon dioxide and steam normally form a majority of negative ions and the flue gas particles are probably also negatively charged in a flame. Negative particles and ions are thereby repelled by a negatively charged electrode which is above the flame zone and are thereby forced downwards in the combustion chamber by the upper electrode and pressed back into the flame zone where they are combusted. The upper part of the combustion chamber acts as an afterburning zone and the content of particulate material (PM), hydrocarbons

(HC) and carbon monoxide (CO) are reduced in the combustion gas. This is also one of the advantages of the invention. Table 2 illustrates the content of these substances without and with electrical influence on the combustion in a combustion chamber as mentioned above with a lateral surface of 50 cm, height of 68 cm and chamber width of 60 cm.

TABLE 2

	Particles per kg combusted mass, spruce acc. to NS 3058	HC ppm	CO vol.%
Without influence	9-12 g/kg	150-210	1,2-2,3
With influence	1-5 g/kg	20-50	0.1-0.5

PATENT CLAIMS

1. A device for use in combustion chambers, such as all types and sizes of stove and fireplace, designed as a container with an inlet for the supply of a fuel and an oxidation means in the form of air and with an outlet for exhaust gas,
characterized in that one or more electrodes are located in such a manner that the flame zone is located between two of the electrodes or between one electrode and a combustion chamber wall and that the electrodes and possibly also the combustion chamber are connected to electrical voltage, thus forming poles in an electrical system.

2. A device for use in combustion chambers according to claim 1, characterized in that one or more electrodes are located in the lower part of the combustion chamber at or under the flame zone and that one or more electrodes are located in the upper part of the combustion chamber at or above the flame zone.

3. A device for use in combustion chambers according to one of the preceding claims,
characterized in that two or more electrodes are located in the upper part of the combustion chamber in such a manner that the flame zone is located between the electrodes, or between one electrode and a combustion chamber wall.

4. A device for use in combustion chambers according to one of the preceding claims.
characterized in that one or more electrodes are located at the inlet for or under the fuel or the grate.

5. A device for use in combustion chambers according to one of the preceding claims.
characterized in that one or more electrodes are located at or in the inlet for air.

6. A device for use in combustion chambers according to one of the preceding claims.

characterized in that one or more electrodes are located at the outlet area for exhaust gas.

7. A device for use in combustion chambers according to one of the preceding claims,
characterized in that electrodes and combustion chamber can be coupled individually to electrical voltage and negative or positive polarity and that the voltage direction can be reversed for periods, and that the voltage may be connected intermittently.

8. A device for use in combustion chambers according to one of the preceding claims,
characterized in that the voltage which is supplied is direct voltage or pulsating direct voltage with a pulse frequency in the range 1Hz to 3000 MHz.

9. A device for use in combustion chambers according to one of the preceding claims,
characterized in that the field strength in the flame zone is in the range 0.01 kV/cm to 30 kV/cm.

10. A device for use in combustion chambers according to one of the preceding claims,
characterized in that one or more electrodes in the lower part of the combustion chamber at or under the flame zone are preferably coupled to positive polarity and one or more electrodes in the upper part of the combustion chamber at or above the flame zone and/or the combustion chamber are preferably coupled to negative polarity.

11. A device for use in combustion chambers according to one of the preceding claims,
characterized in that one or more electrodes are provided around the fuel in the lower part of the combustion chamber.

12. A device for use in combustion chambers according to one of the preceding claims when a mixing chamber is used, thus forming one or more afterburning zones.

characterized in that the mixing chamber is equipped with electrodes or is employed as an electrode.

13. A device for use in combustion chambers according to one of the preceding claims,
characterized in that the electrodes on each side of the flame zone can be located at any angle whatever in relation to one another and the flame zone, preferably parallel to one another.

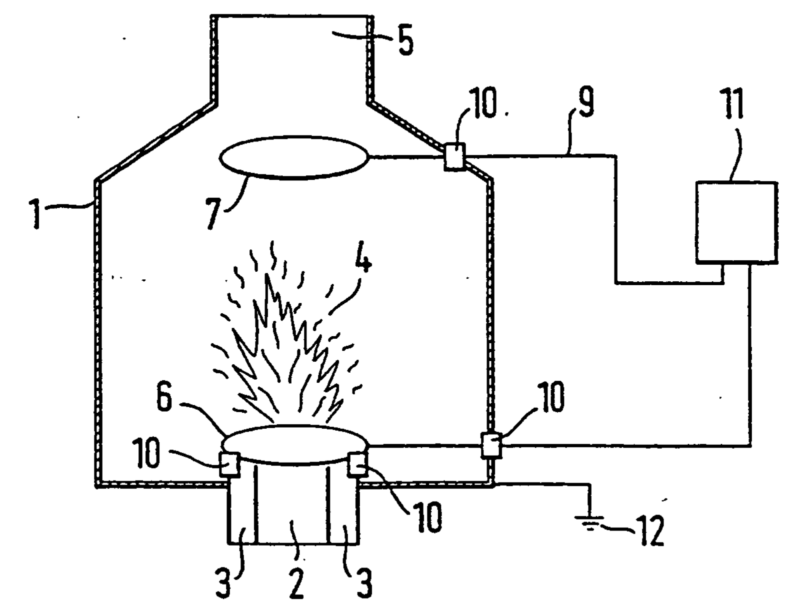

Fig. 1

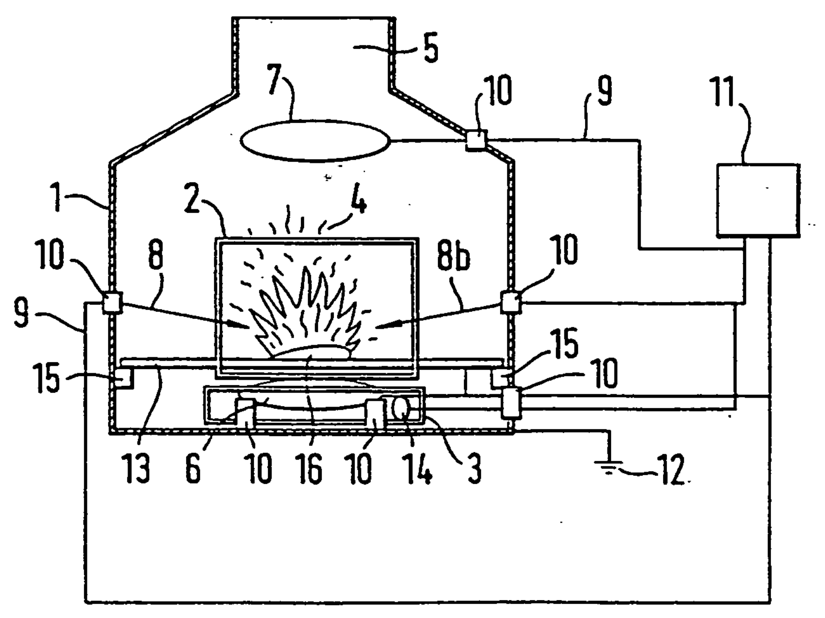

Fig. 2

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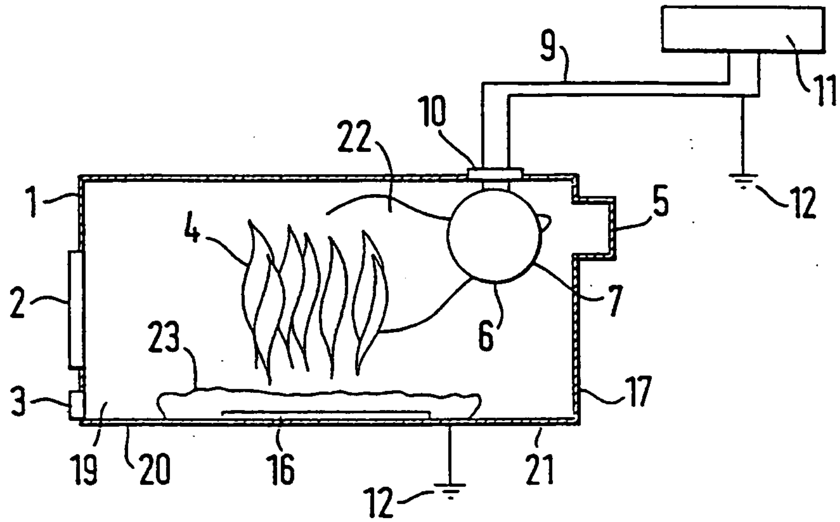
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Fig. 3.1

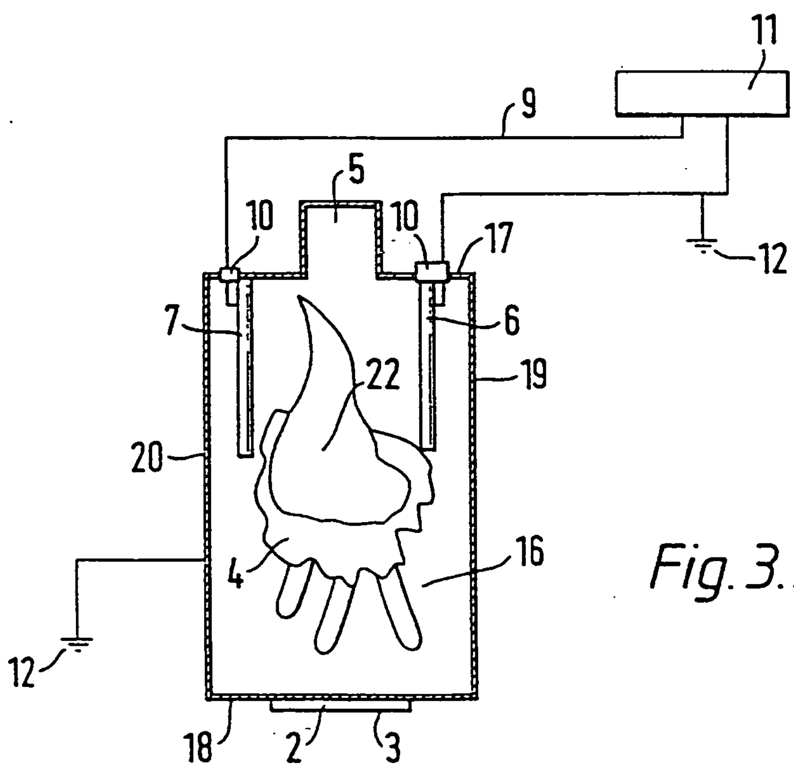
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Fig. 3.2

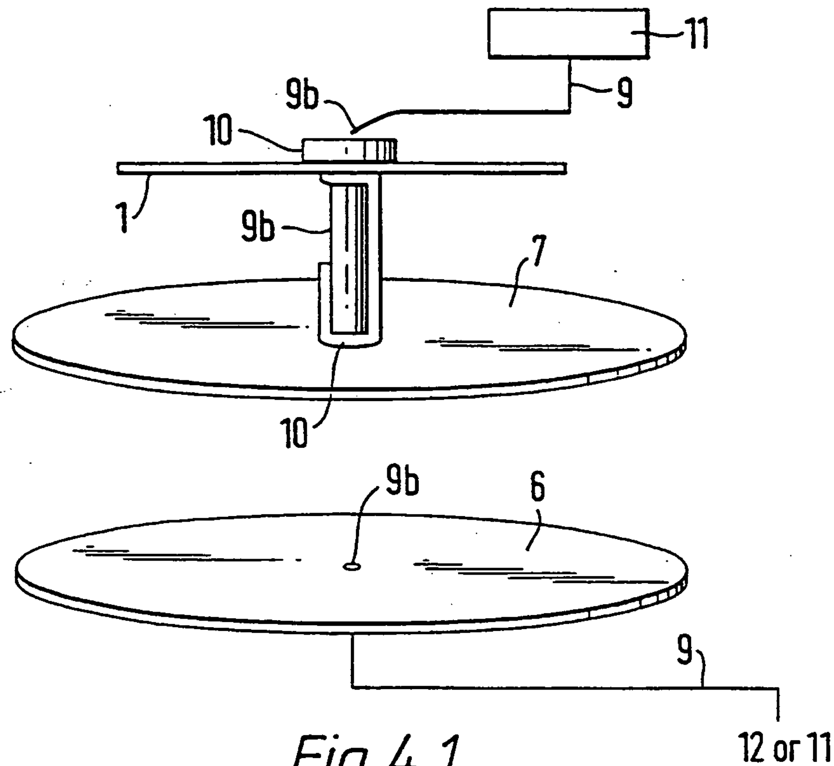

Fig. 4.1

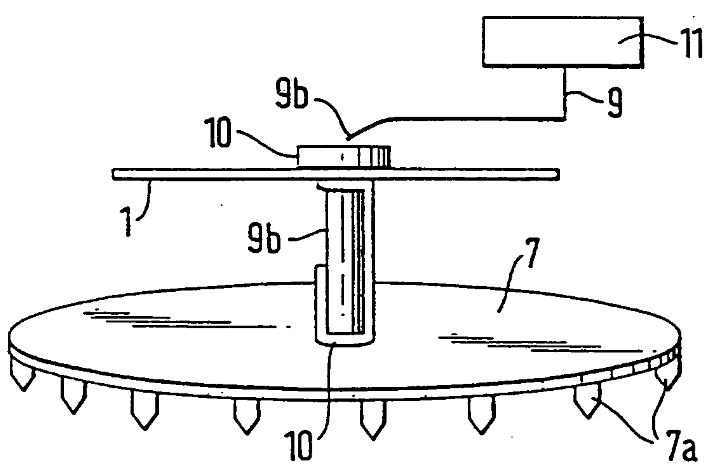

Fig. 4.2

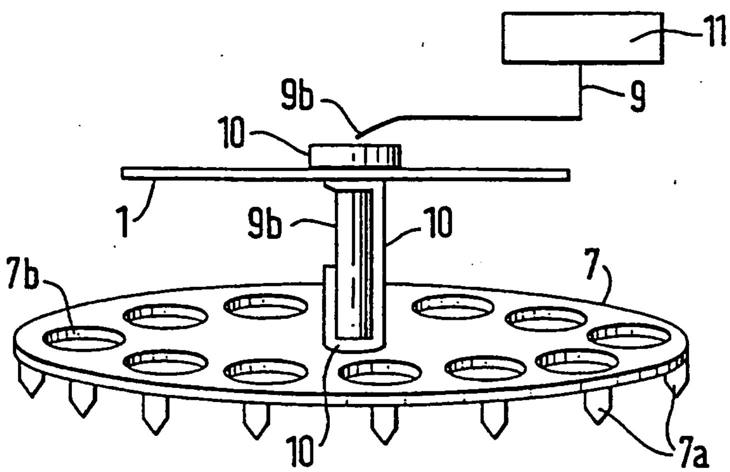
11
9b
9
10
1
9b
10
7b
7
10
7a

Fig. 4.3

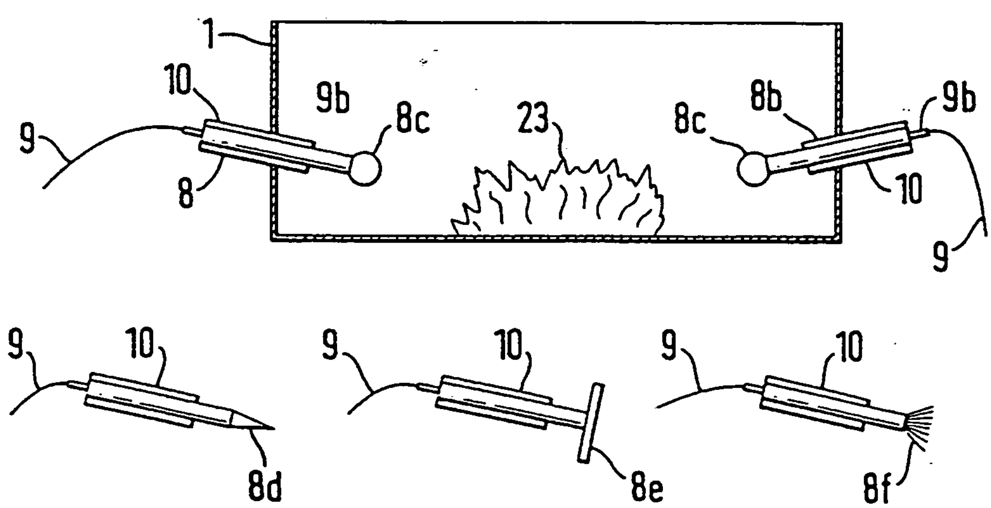
1
10
9b
8c
23
8c
8b
9b
9
8
10
9
9
10
9
10
9
10
8d
8e
8f

Fig. 4.4

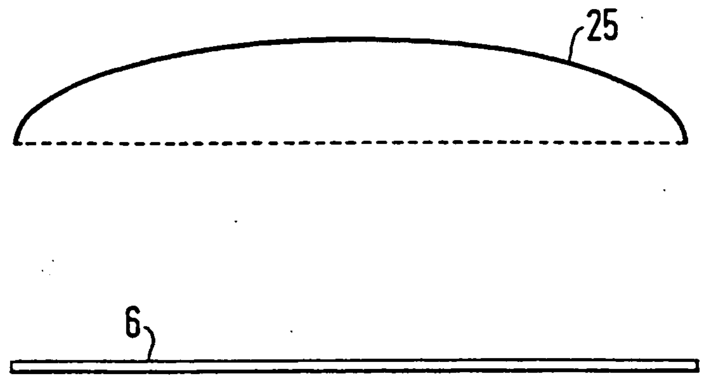

Fig. 4.5

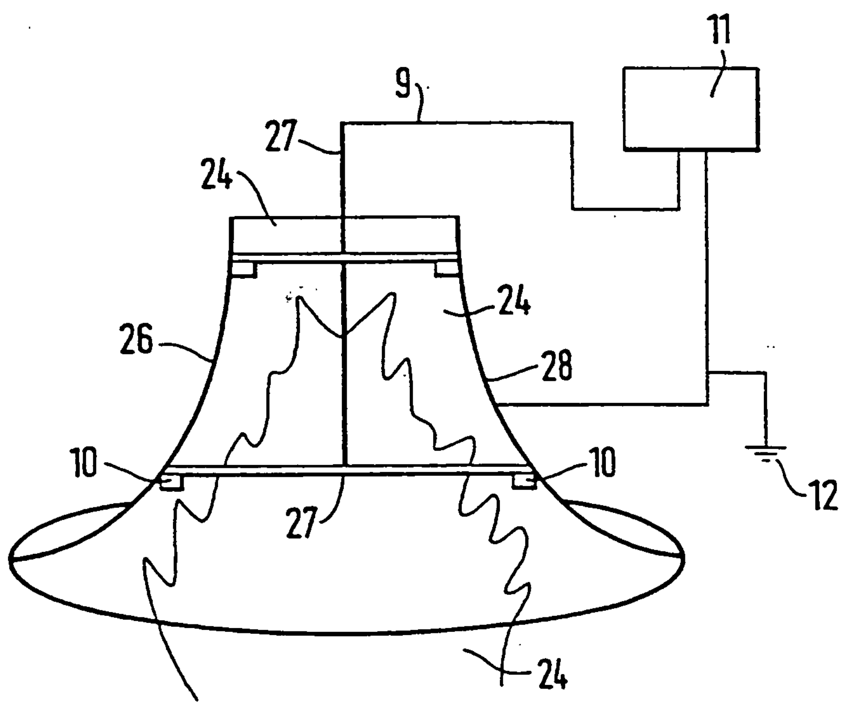

Fig. 4.6

SUBSTITUTE SHEET

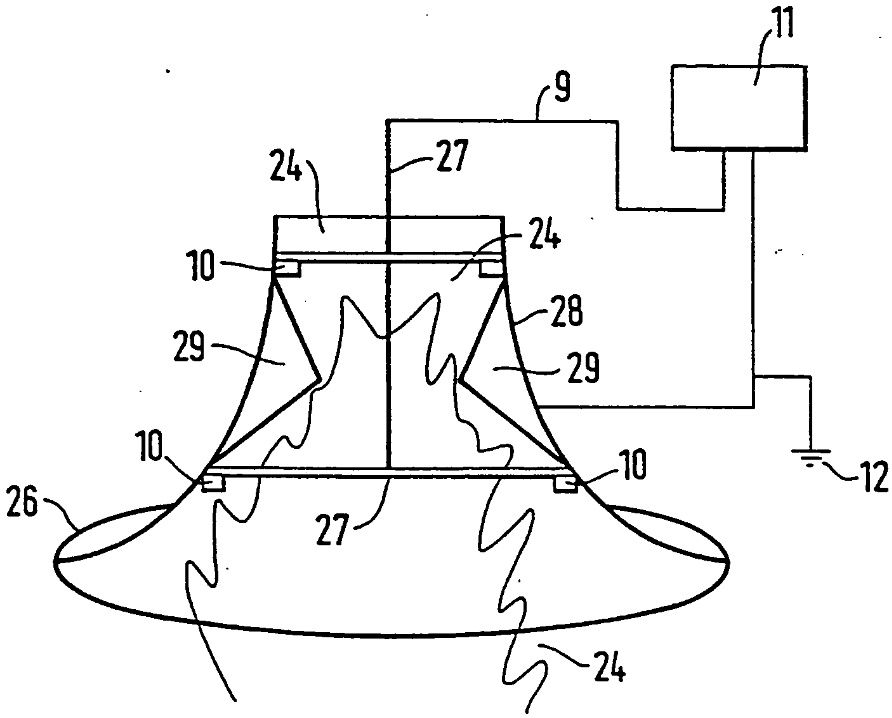

Fig. 4.7

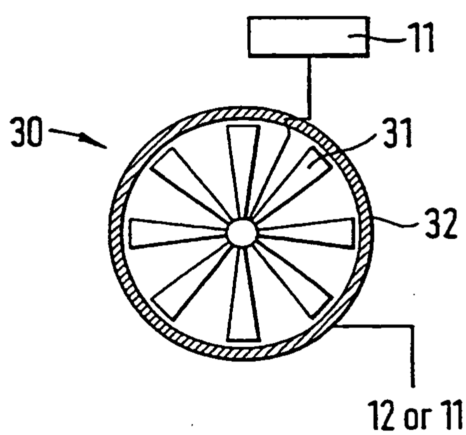

Fig. 4.8

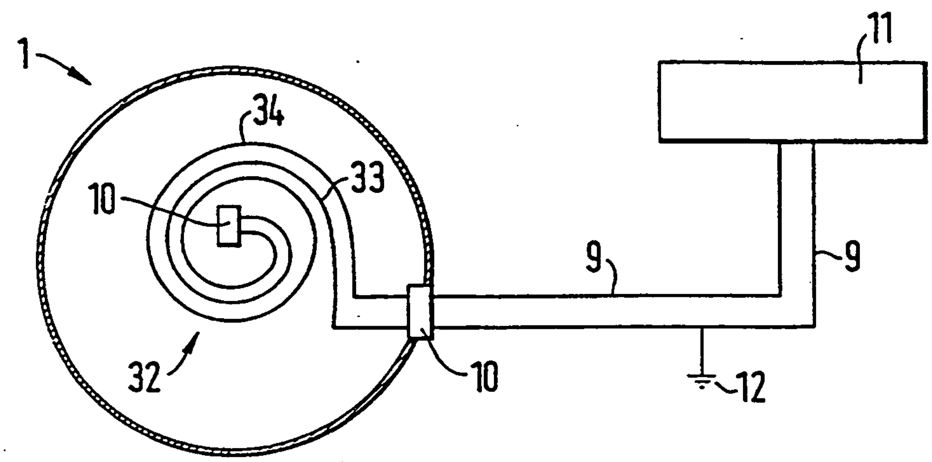

Fig. 4.9

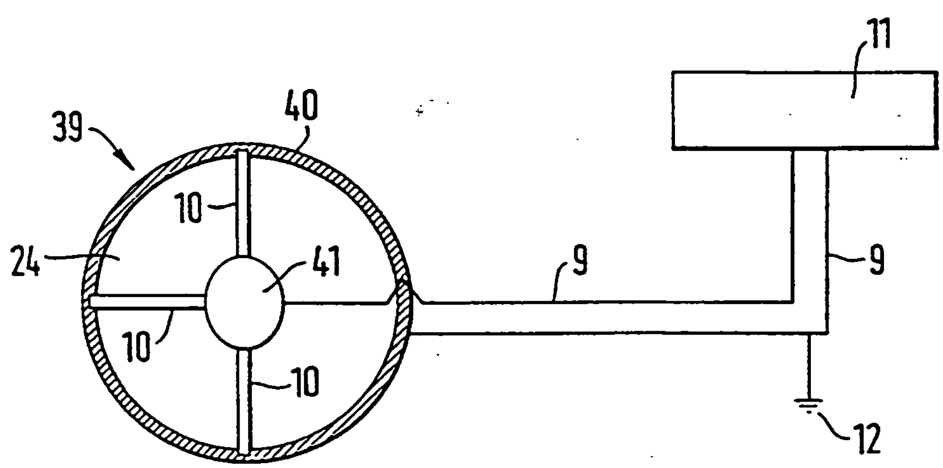

Fig. 4.10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 95/00118

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F23C 11/00, F23B 7/00 // F23D 14/68
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F23B, F23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3087472 A (ASAKAWA), 30 April 1963 (30.04.63), column 1, line 58 - column 2, line 23; column 3, line 22 - column 4, line 9, figures 1,8 --	1,2,8,10
X	EP 0212379 A2 (KEESMANN), 4 March 1987 (04.03.87), column 7, line 6 - line 26, figure 5 --	1,2
X	GB 1013015 A (KJELLSTROM), 15 December 1965 (15.12.65), page 2, line 5 - line 45 --	1
X	SE 182925 C1 (KJELLSTRÖM), 19 March 1963 (19.03.63), page 2, column 1, line 20 - line 40, figure 1 --	1

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 November 1995	27 -11- 1995

Name and mailing address of the ISA/	Authorized officer
Swedish Pat nt Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Anders Bruun Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 95/00118

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3841824 A (BETHEL), 15 October 1974 (15.10.74), column 3, line 66 - column 6, line 13, figures 6,7	1
A		2
	--	
X	SE 130123 C (METAL, CARBIDES CORPORATION), 21 November 1950 (21.11.50), Page 2, column 1, last paragraph; page 3, column 1, second paragraph	1,10
	--	
X	US 5091779 A (SÄUFFERER ET AL), 30 May 1978 (30.05.78), column 6, line 5 - line 17	1,10
	--	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO95/00118

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

.../...

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.: 1,2,8,10

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☒ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO95/00118

The subject-matter of claim 1 is previously disclosed by US 3087472.

Claim 2 relates to the arrangement of electrodes both in the upper part and in the lower part of the combustion chamber.
Claim 3 relates to the arrangement of electrodes in the upper part of the combustion chamber.
Claim 4 relates to the arrangement of electrodes in the fuel feeding opening or below the fuel or the grate.
Claim 5 relates to the arrangement of electrodes in the air feeding opening.
Claim 6 relates to the arrangement of electrodes in the exhaust discharge area.
Claim 7 relates to intermittent or individually adjustable voltage of the electrodes.
Claim 8 relates to the frequency of the electric field.
Claim 9 relates to the strength of the electric field.
Claim 10 relates to the polarity of a vertical electric field.
Claim 11 relates to the arrangement of electrodes around the fuel in the lower part of the combustion chamber.
Claim 12 relates to the application of electrodes to mixing chambers, or to the use of mixing chambers as electrodes.
Claim 13 relates to the angular position of the electrodes.

INTERNATIONAL SEARCH REPORT

30/10/95

International application No.
PCT/NO 95/00118

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US-A-	3087472	30/04/63	NONE		
EP-A2-	0212379	04/03/87	SE-T3-	0212379	
			DE-A-	3529893	26/02/87
			DE-U-	8701774	26/03/87
GB-A-	1013015	15/12/65	NONE		
SE-C1-	182925	19/03/63	NONE		
US-A-	3841824	15/10/74	NONE		
SE-C-	130123	21/11/50	NONE		
US-A-	5091779	30/05/78	DE-C-	3928052	27/09/90
			EP-A-	0415152	06/03/91